CATALOG OF SELECTED NMAB REPORTS

NATIONAL MATERIALS ADVISORY BOARD
Division of Engineering - National Research Council

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As a part of the National Research Council, the National Materials Advisory Board performs study, evaluation, or advisory functions through groups composed of individuals selected from academic, governmental, and industrial sources for their competence and interest in the subject under consideration. Members of these groups serve as individuals contributing their personal knowledge and judgments and not as representatives of any organization in which they are employed or with which they may be associated.

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INTRODUCTION

The National Materials Advisory Board (NMAB) was established in January 1969, as successor to the Materials Advisory Board. Its predecessor Board was appointed in 1951 by the National Academy of Sciences as the Metallurgical Advisory Board, and through a series of changes and expansion of scope became the Materials Advisory Board in 1954. This current change in name to the National Materials Advisory Board reflects its expanded role in the materials problems and issues of concern to industry and other non-government sectors of the materials community; however, the traditional advisory services to government and general modus operandi within the National Research Council continue unchanged.

Within the scope of the two Academies (National Academy of Sciences and National Academy of Engineering) the general purpose of the National Materials Advisory Board is the advancement of materials science and engineering in the national interest. More specifically, the Board undertakes to define technical problems, potential solution approaches, and opportunities of national concern and relevance to government, industry, or academia, attempting thereby to stimulate appropriate action. In addition, it aims to provide both a forum and focal point for discussing national materials issues and for planning, coordinating, and guiding comprehensive programs to achieve defined goals. (See inside back cover of this catalog.)

During 1970, ad hoc committees were actively engaged in a wide variety of studies requested by agencies of the government. For the Director of Defense Research and Engineering, these included studies on systematic evaluation of materials for structural applications, on atmospheric deterioration of superalloys, on technological forecasting in engineering materials, on engineering aspects of massive glass as a structural material, on testing for prediction of material

performance in structures and components, on accelerated utilization of new materials, and on government beryllium programs; for the Naval Ordnance Systems Command, a study on gun tube technology; for the National Aeronautics and Space Administration, a study of protective coatings for high-temperature materials; for the Office of Naval Research, studies on the fundamentals of massive glass as a structural material, on research program formulation in structural mechanics, and on fundamentals of laser glass; and for the General Services Administration (on behalf of GSA, Office of Emergency Preparedness, Department of the Interior, and Department of Commerce), a study of the effects of new technology on the supply and demand of critical and strategic materials.

In its meetings and advisory services to the government, the National Materials Advisory Board is continuing the operational concepts of its predecessor organization, the Materials Advisory Board. Different approaches, however, are required for the identification and treatment of materials problems and issues that are germane to the non-government sectors. Suitable mechanisms for bringing such matters into focus and for providing the necessary funding to support this type of activity are being evolved.

In addition to the specific studies noted above, the Board has provided assistance in a variety of activities which involve materials, such as cooperation among materials oriented technical societies, development of background information for national materials policy, definition of needs for studies in the field of biomaterials, and other topics.

At present, members of the National Materials Advisory Board number 19 (see inside front cover of this catalog). In addition, during 1970 there were 317 experts in materials and allied sciences who contributed their time and knowledge as members of committees and panels engaged in specific studies. Forty-five such committees and panels were active during the year involving a total of 88 meetings at various locations throughout the country.

REPORTS

Most of the reports issued by the National Materials Advisory Board are prepared for the primary purpose of presenting the findings, conclusions, and recommendations of NMAB committee studies to the organizations that request the studies and that support the cost thereof under contract to the Academies.

Reports of studies requested by government agencies are printed in sufficient quantity for distribution within the requesting agency, to other government agencies having an interest in the subject, to other organizations selected by the requesting agency, and to members of NMAB. In addition, a limited number of copies are held in the office of the Board for file reference and, if not in a restricted area, for selected additional distribution, while the supply lasts. Because many of the reports concern subjects of definite interest to people in the materials community at large, steps have been taken to make these reports broadly available through channels explained elsewhere in this catalog.

PURPOSE OF THIS CATALOG

Our purpose here is to acquaint the national community of materials scientists and engineers with the studies, many of national import, that have been pursued by NMAB over the past five years, and thereby, to foster a better and wider understanding of the Board's activities. Toward this end, the catalog provides a listing of 64 selected NMAB reports issued from 1965 through 1971, with an abstract of each.

INFORMATION ON AVAILABILITY AND CHARGES

Each report is identified by number (listed in ascending order), title, number of pages, date of issue, and organization from which it can be obtained (NMAB or NTIS, or both).

Where the word "Yes" appears below the heading "Available from NMAB," a report may be obtained at no charge by writing the National Materials Advisory Board. This procedure holds only as long as extra copies are available. The address is:

National Materials Advisory Board
National Academy of Sciences
2101 Constitution Avenue, N.W.
Washington, D.C. 20418

Where a report is shown to be unavailable from NMAB, it may be ordered from the National Technical Information Service (NTIS) by the NTIS identification number. The address of NTIS is:

U. S. Department of Commerce
National Technical Information Service
5285 Port Royal Road
Springfield, Virginia 22151

Make check or money order payable to National Technical Information Service. The charge per copy is $3, except for the following, which cost $6 per copy:

MAB-201-M	MAB-212-A-M	MAB-221-M	MAB-232-M
MAB-205-M	MAB-216-M	MAB-222-M	MAB-236
MAB-206-M(7)	MAB-217-M	MAB-225-M	MAB-245
MAB-207-M	MAB-220-M	MAB-229-M	MAB-247

There are also three NMAB reports which, because of their importance and broad interest, have been published by the National Academy of Sciences. These are as follows:

Report NMAB-272, Proceedings of the Beryllium Conference - $10.00

NAS Publication 1576, Ceramic Processing - $15.00

NAS Publication ISBN-0-309-01769-6, *High-Temperature* Oxidation-Resistant Coatings - $12.50

These may be purchased from:

Printing and Publishing Office
National Academy of Sciences
2101 Constitution Avenue, N.W.
Washington, D.C. 20418

Make checks payable to National Academy of Sciences.

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The index on the following page arranges the reports (by report number) into separate categories, as a guide to selective interests.

INDEX BY INTEREST CATEGORIES

(NMAB Report No.)

*This book is the full report of the NMAB study.

LIST OF SELECTED NMAB REPORTS

Report No.	Title	Available from NMAB	NTIS No.
MAB-201-M	Procedures for Evaluating Coated Refractory Metal Sheet (Supersedes MAB-189-M), 35 pp., 8/64	No	AD605453
MAB-205-M	Evaluation Test Methods for Beryllium, 49 pp., 3/66	Yes	AD631183
MAB-206-M(7)	Metalworking Processes and Equipment, 72 pp., 9/68	Yes	AD675784
MAB-207-M	Micromechanics of Fibrous Composites, 72 pp., 5/65	No	AD467241
MAB-210-M	Coated Refractory Metal Technology-1965, Oxidation-Resistant Coatings for Refractory Metals, 110 pp., 11/65	Yes	AD475754
MAB-211-M	Status of the Purification of Beryllium, 66 pp., 10/65	Yes	AD473957L
MAB-212-M	Final Report of the Refractory Metals Sheet Rolling Panel, 172 pp., 3/66	Yes	AD481504
MAB-212A-M	Summary Report of the Refractory Metals Sheet Rolling Panel, 12 pp., 6/66	Yes	AD636180
MAB-214-M	The Interface Problems in Fibrous Composites, 42 pp., 11/65	No	AD630256
MAB-215-M	Composites, 97 pp., 11/65	No	AD477860
MAB-216-M	Evaluation Test Methods for Refractory Metal Sheet Materials (Supersedes MAB-192-M), 38 pp., 11/65	Yes	AD625606
MAB-217-M	Cooperative Analysis Program on Refractory Metal Alloys, 39 pp., 2/66	Yes	AD630276
MAB-220-M	Final Report of the Panel on Lubrication to the ad hoc Committee on Metalworking Processes and Equipment, 29 pp., 9/65	Yes	AD630689
MAB-221-M	Theoretical Strength of Materials, 112 pp., 8/66	Yes	AD636917
MAB-222-M	Principles of Research-Engineering Interaction, 350 pp., 6/66	No	AD636529
MAB-225-M	Materials Evaluation Techniques, 16 pp., 8/66	Yes	AD638971

Report No.	Title	Available from NMAB	NTIS No.
MAB-226-M	Characterization of Beryllium, 7 pp., 8/66	Yes	AD640210
MAB-227-M	Informal Study and Recommendations Regarding Corrosion, 6 pp., 8/66	Yes	AD640055
MAB-229-M	Characterization of Materials, 441 pp., 3/67	No	AD649941
MAB-232-M	Guidelines for Refractory Alloy Tubing Specifications, 37 pp., 10/67	Yes	Ad662057
MAB-236	Structural Design with Fibrous Composites, 127 pp., 10/68	Yes	AD682493
MAB-238	Trends in Usage of Beryllium & Beryllium Oxide, 17 pp., 2/68	Yes	AD832579
MAB-240	Trends in Usage of Platinum, 11 pp., 2/68	No	AD832581
MAB-241	Trends in Usage of Silver, 15 pp., 2/68	Yes	AD832582
MAB-242	Trends in Usage of Tantalum, 14 pp., 2/68	No	AD832583
MAB-243	Infrared Transmitting Materials, 59 pp., 2/68	Yes	AD837431
MAB-245	Application of Science and Technology to Metalworking, 21 pp., 9/68	Yes	AD677718
MAB-246	An Approach for Systematic Evaluation of Materials for Structural Application, 52 pp., 2/70	Yes	AD705664
MAB-247	Technological Influence on Usage of Platinum and Palladium, 19 pp., 12/68	Yes	AD681367
MAB-248	Applications of Nickel, 103 pp., 12/68	Yes	AD846999
MAB-249	Usage of Titanium and Its Compounds with Comments on Scrap and Sponge, 106 pp. 2/69	Yes	AD848925
MAB-250	Trends in Usage of Hafnium, 11 pp., 12/68	No	AD847000
MAB-251	Trends in Usage of Rhenium, 9 pp., 12/68	No	AD848593
NMAB-252	Non-Destructive Evaluation, 116 pp., 1/69	No	AD692491
NMAB-254	Trends in Usage of Gold, 15 pp., 9/69	Yes	AD693869
NMAB-255	Trends in Usage of Cadmium, 15 pp., 11/69	Yes	AD700744
NMAB-256	Trends in Usage of Chromium, 88 pp., 5/70	Yes	AD707175
NMAB-257	Usage Patterns for Tellurium, 25 pp., 8/69	Yes	AD693870
NMAB-258	Trends in Usage of Mercury, 37 pp., 9/69	Yes	AD693871

Report No.	Title	Available from NMAB	NTIS No.
NMAB-259	Quantitative Techniques for Research Program Planning in Structural Mechanics, 62 pp., 8/69	Yes	AD696974
NMAB-260	Hot Corrosion in Gas Turbines 70 pp., 5/70	Yes	AD870745
NMAB-261	Fundamentals of Massive Glass as a Naval Structural Material, 86 pp., 3/70	Yes	AD703860
NMAB-262	Massive Glass as a Naval Structural Material, 98 pp., 4/70	Yes	AD706223
NMAB-263	Summary Report-High Temperature Oxidation Resistant Coatings, 54 pp., 2/70	No	PB193400
NMAB-264	Trends in Usage of Columbium, 75 pp., 3/70	Yes	PB193595
NMAB-265	Trends in the Use of Tin, 52 pp., 3/70	Yes	PB193596
NMAB-266	Trends in Usage of Rare Earth, 67 pp., 10/70	Yes	PB196330
NMAB-267	Trends in the Use of Vanadium, 46 pp., 3/70	Yes	PB193597
NMAB-268	Trends in the Usage of Bismuth, 30 pp., 8/70	Yes	PB194493
NMAB-269	Trends in the Usage of Fluorspar, 54 pp., 12/70	Yes	PB198339
NMAB-270	Advanced Technology for Naval Gun Tubes, 70 pp., 2/71	Yes	AD722793
NMAB-271	Fundamentals of Damage in Laser Glass, 80 pp., 7/70	Yes	AD709421
NMAB-272	Proceedings of Beryllium Conference* (Vol.I), 655 pp., 8/70	No	Not Available
NMAB-274	Trends in Usage of Antimony, 113 pp., 12/70	Yes	PB197261
NMAB-275	Trends in Usage of Depleted Uranium, 172 pp., 6/71	Yes	PB203685

* available from NAS - $10.00

Report No.	Title	Available from NMAB	NTIS No.
NMAB-276	Trends in the Use of Ferroalloys by the Steel Industry of the United States, 116 pp., 7/71	Yes	PB204142
NMAB-277	A Delphi Exploration of the U. S. Ferroalloy and Steel Industries, 112 pp., 7/71	Yes	PB204143
NMAB-278	Processes for Extracting Alumina from Non-bauxite Ores, 88 pp., 12/70	Yes	PB198507
NMAB-279	Technological Forecasting and its Application to Engineering Materials, 41 pp., 3/71	No	AD726221
NMAB-281	Report of the Ad Hoc Committee on Beryllium, 93 pp., 10/71	Yes	AD732482
NMAB-283	Accelerated Utilization of New Materials, 96 pp., 5/71	No	AD727178
NMAB-284	Fundamentals of Amorphous Semiconductors, 187 pp., 9/71	No	AD731072
NAS Publication 1576	Ceramic Processing (Book, 298 pp.) 1968*	No	Not available
NAS Publication ISBNO-309-01769-6	High Temperature Oxidation Resistant Coatings, 223 pp., 1970**	No	Not Available

* available from NAS - $15.00
** available from NAS - $12.50

REPORT ABSTRACTS

Report No.	Title

MAB-201-M PROCEDURES FOR EVALUATING COATED REFRACTORY METAL SHEET (35 pp)

Described in this report are procedures for (1) Screening tests for oxidation characteristics, effect of coating process and coating on bend transition temperature of alloy, reproducibility of composite (coating plus alloy), effect of coating process on substrate and producibility and compatibility; (2) Advanced tests (mechanical) - tensile (room and elevated temperature), stress rupture, creep and fatigue; (3) Advanced tests(other) - oxidation in reduced-pressure flowing air, coating tolerance for pre-strain.

Appendices cover procedures for optical temperature measurement and high temperature mechanical testing, and suggested apparatus for reduced pressure oxidation tests.

MAB-205-M EVALUATION TEST METHODS FOR BERYLLIUM (49 pp)

This report was prepared to establish standardized methods and procedures for conducting mechanical property tests on beryllium. Such methods are required in view of the characteristics of beryllium, which make conventional test procedures difficult to apply. The data presented are restricted to information which is well established and accepted, but also identified are areas of controversy in testing and current technical needs in the testing area. Recommended procedures for tensile, 3-point bend, 4-point bend and precision elastic limit tests are described, based on a review of methods used in several organizations.

MAB-206-M(7) METALWORKING PROCESSES AND EQUIPMENT (72 pp)

In 1963, the Office of Director of Defense Research and Engineering requested the Materials Advisory Board to provide advice and guidance to the Steering Group of the government's Metalworking Processes and Equipment Program. The program was a coordinated effort of the Army, Navy, Air Force and NASA to identify salient factors which limit metal deformation processes and concurrently to sponsor research to extend these limits for improvement of manufacturing capabilities.

This is the final report of the committee. The advice of the committee and its two panels (one on Lubrication in Metalworking--Report MAB-220-M, and the other on Application of Deformation Theory to Practice--Report MAB-245) is in the form of 34 recommendations for R&D in the following areas of metalworking: Vibrational Energy; Hydrostatic Extrusion; Laboratory Measurements of Mechanical Properties; Superplasticity; Ductile Fracture; The Application of Computers to Deformation Processing; Heat Transfer; Crystal Mechanics; The Function of Continuum Mechanics in the Analysis and Design of Metalworking Processes; Lubrication; Application of Deformation Theory to Practice; Limitations of Extrusion Processes; Thin Sheet Rolling; The Use of Computers in Forging Die Design; The Use of Model Experiments in Forging Die Design; The Application of Plasticity Mechanics to Forging Die Design; Mechanics of Ductile Fracture; Formability Limits; Incremental Forming; High Energy Rate Forming; Plastic Strain Cycling.

MAB-207-M MICROMECHANICS OF FIBROUS COMPOSITES (110 pp)

When external loads or other stress-inducing forces are applied to a composite of fibers embedded in a matrix, internal stresses are set up in each constituent and at the same time complex interactions occur between them. The study of these internal stresses, the internal mechanics of the reactions of the constituents, separately and in concert, to the imposed forces, may be called the micromechanics of fibrous composites. The reasons for theoretical and experimental research in micromechanics are (1) to clarify the behavior of fibrous composites and thereby to improve the design of engineering structures based on them, and (2) to improve the properties of composites. In this study, the subject was divided into six areas. Certain aspects of each area were treated with respect to the significance of the area,

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the state of present knowledge, the still unanswered questions, and suggested lines of attack for research.

MAB-210-M COATING REFRACTORY METAL TECHNOLOGY - 1965, OXIDATION-RESISTANT COATINGS FOR REFRACTORY METALS (110 pp)

The Coating Subpanel of the Refractory Metals Sheet Rolling Panel reviewed and evaluated the current state of the art of coatings for the refractory metals columbium, molybdenum, tantalum, and tungsten. It concluded that a satisfactory technology existed to coat columbium and molybdenum for short-time oxidizing applications at temperatures as high as 2800 to 3000F. At this time coatings for tantalum were in an early stage of development, and satisfactory coatings were not available for protecting tungsten above 3500F. It was felt that a coating system must be selected and optimized for each alloy, component design, and for the mission it is to perform. Detailed conclusions were presented for all aspects of coating technology, as a basis for twelve recommendations concerned with advancing the state of the art.

MAB-211-M STATUS OF THE PURIFICATION OF BERYLLIUM (66 pp)

The objective of the Panel study which culminated in this report was to describe the then capabilities in purification, the advances which could reasonably be expected in the future, and the implications of purification on utilization or research. The characteristics of several purification and consolidation techniques, the effects of specific elements on ductility and strength of beryllium and the problems associated with mechanical property evaluation of high purity beryllium are described. The report concludes with four specific recommendations.

MAB-212-M FINAL REPORT OF THE REFRACTORY METALS SHEET ROLLING PANEL (172 pp)

The objectives of this study were to identify causes responsible for variation in refractory metal sheet and to develop remedies for these difficulties. While DoD sponsored the study, NASA and AEC also took an active part in it. The genesis, method of operation, and accomplishments of the main panel are described in the report, along with reflections on the conduct of such a program and recommendations for future activities in this field. Summary reports of the eleven subpanels and one special ad hoc subpanel are included in the body of the report. Longer discussions of activities of the Subpanel on Alloy Requirements & Selection constitute an appendix.

MAB-212A-M SUMMARY REPORT OF THE REFRACTORY METALS SHEET ROLLING PROGRAM (12 pp)

The method of operation, accomplishments, and recommendations of the Panel are outlined (summarizing the contents of MAB-212-M, "Final Report of the Refractory Metals Sheet Rolling Panel").

MAB-214-M REPORT OF THE AD HOC COMMITTEE ON INTERFACE PROBLEMS IN FIBROUS COMPOSITES (42 pp)

Fibrous composites consist of three basic elements: the fibrous phase, the matrix phase, and the interface between these two. Once the composite is formed, the interface is the critical region in transferring load between matrix and fiber. The broad knowledge extant in surface and interfacial phenomena is difficult to apply to fibrous composites in any meaningful fashion because of the inherently complicated interrelationships among the components. This lack of understanding deprives engineers of needed guidance in improving existing composites and in developing new composites, and impairs the value of experimental research in other aspects of composites technology.

Because the nature of an interface is a function of the entire history of the composite, this report dealt with the fiber surface, the process of composite formation, retention of

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properties in service, and the interface during composite failure. The approach used in this study was to develop a general awareness of the state of knowledge of interface characteristics in fibrous composites and to assess the relevance of interface characteristics to composite performance. The objective was to display potentially critical facets of the situation in order to identify areas in which additional research is needed and to make recommendations for strengthening the research effort in this field.

MAB-215-M COMPOSITES (97 pp)

This study identified research and development problems which limited the further advance of composites technology. The scope was confined to fibrous, lamellar and skeletal composites for structures, thermal applications, radiation barriers or windows, and armor. In assessing the problems, attention was given to each step in the development sequence, which involves materials selection, design of composite, processing to form the composite, evaluation of composites, structural design using composites, and the role and limitations of composites in future weapons systems.

The study found that particular problems existed in each of these steps. These are associated with such subjects as internal mechanics, interface bonding, environmental effects, fabrication, multi-axial load performance, testing techniques, and high fiber cost.

Recommendations for R&D efforts and other appropriate actions are included.

MAB-216-M EVALUATION TEST METHODS FOR REFRACTORY METAL SHEET MATERIALS (38 pp)

This is the third revision of recommended test methods for refractory metal sheet published by the Materials Advisory Board Refractory Metals Sheet Rolling Panel. The objective was to provide a standard basis for the test evaluation of sheet materials produced under various Department of Defense development programs. After a canvas of suppliers and users of refractory sheet metals, the first recommendations were published in September 1961 as MAB Report 176-M to define common tensile, creep-rupture, bend, and thermal properties tests. Subsequently, as the Department of Defense programs progressed, more specialized tests became necessary to evaluate fabrication characteristics and to provide preliminary design data. Again, after discussion with principal organizations engaged in direct applications, a revised edition was published April 22, 1963, as MAB-192-M. This third revision is based on a review, by the panel and qualified individuals representing governmental and commercial laboratories, of further criticisms and comments.

MAB-217-M COOPERATIVE ANALYSIS PROGRAM ON REFRACTORY METAL ALLOYS (39 pp)

As a part of the Refractory Metals Sheet Rolling Program, reference materials (unalloyed W, T-111 Ta, FS-85 Cb, and TZM Mo) were prepared and analyzed by 25 cooperating laboratories. No serious problems were encountered in determining alloying elements. Hydrogen and carbon determinations could be made satisfactorily at the levels encountered, but agreement on oxygen and nitrogen was not satisfactory below the 10 ppm level. Recommendations for research to solve remaining problems were offered.

MAB-220-M FINAL REPORT OF THE PANEL ON LUBRICATION TO AD HOC COMMITTEE ON METALWORKING PROCESSES AND EQUIPMENT (29 pp)

The study resulting in this report is part of the work described under MAB-206-M(7)--see above. The Panel on Lubrication surveyed the state of knowledge of friction and lubrication as they related to deformation processes and equipment. This report summarizes the findings and presents five recommendations relating to communication between lubrication specialists and metalworking specialists, thick film lubrication, screening tests, solid lubricants, and compatibility of contacting metals.

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MAB-221-M THEORETICAL STRENGTH OF MATERIALS (112 pp)
The wide difference in strength between what is presently realizable in the materials of commerce and what is assumed to be theoretically possible is of continuing concern. This study was conducted to summarize the procedures for estimating theoretical strength, together with examples of calculations of maximum strength for different classes of materials. The report deals with five areas: theoretical considerations for ideal solids, cohesive strength of crystals, strength of inorganic glassy solids, strength of organic polymers, and examples of theoretical strength calculations. Equations suitable for engineering purposes are developed for each class, along with a discussion of the assumptions involved, and the limitations and uncertainties applicable to the expression of strength in terms of other properties which are measurable experimentally. The report sets forth the considerations upon which the concept of theoretical strength is based, the methods by which calculations can be made, the information required to make the calculations quantitative, the sources of such information, and the level of confidence to be placed upon the results applicable to various types of materials.

MAB-222-M PRINCIPLES OF RESEARCH-ENGINEERING INTERACTION (350 pp)
A technique of analysis was developed and applied to ten case histories to identify common elements and patterns which might be used as guides by DoD to stimulate research-engineering interactions in the solution of materials problems. The analysis identified several elements which enhanced success in many of the cases. Among these are: (1) Flexibility for the individual investigators to make major changes in direction and goals, (2) Close and frequent communications between organizationally independent groups, (3) The existence of key individuals who bridged the geographical, organizational, and functional barriers between groups, (4) The recognition of an important need (most frequently the principal factor), (5) Recognition that an available dormant approach was pertinent to a specific need. It was recommended that the findings be considered in future materials research and engineering efforts of DoD, and that the value of the case history approach as an educational tool be emphasized. A series of questions was developed to aid further self study by research and development organizations, and the need for more effective tools of case history analysis was identified.

MAB-225-M MATERIALS EVALUATION TECHNIQUES (16 pp)
This is the report of an ad hoc group formed to determine the need for an NMAB study of the subject, and if need were shown, to recommend the mode of attack. The group recommended the formation of a panel to (1) identify systems, components, environments and design criteria and, (2) relate these factors to test techniques and trade-off studies. From this base guidelines could be drawn on approaches to materials evaluation, trade-off studies, development of test methods, and design data generation. The recommendations of this group resulted in the formation of an NMAB panel, the findings of which are reported in NMAB-246, An Approach for Systematic Evaluation of Materials for Structural Application (see below).

MAB-226-M CHARACTERIZATION OF BERYLLIUM (7 pp)
This report called for more adequate characterization of beryllium intended for military applications, which had languished because of lack of reproducible performance and the inability to relate unexpected behavior to prior processing. The report compiled the major process variables attending the principal operations involved in producing a beryllium mill product, and then a part. This compilation comprised a check list which should be reviewed at the start of a research or development effort to ensure that variables which might be significant are not being overlooked. The ultimate objective of obtaining and collating such data is to assure uniformity, and thus introduce reliability into manufactured parts.

Report No.	Title

MAB-227-M INFORMAL STUDY AND RECOMMENDATIONS REGARDING CORROSION (6 pp)

A broad look was taken of the corrosion problem in order to recommend whether or not a deeper study by another committee was needed. There was agreement as to the unsatisfactory manner in which current corrosion problems are usually handled, and regarding the inadequate training of engineers. The formation of a group to provide documentation on a number of specific topics was strongly recommended. These included a summary of the major corrosion problems, our capabilities for attacking these problems, the effectiveness of prevailing methods, and areas needing improvement.

MAB-229-M CHARACTERIZATION OF MATERIALS (441 pp)

This study was initiated to suggest guidelines for the development of a science of materials that would afford predictable and reliable results in devising and engineering new materials for high performance applications, both military and industrial. The keynote to such a science is characterization. A definition evolved by the committee is "characterization describes those features of the composition and structure (including defects) of a material that are significant for a particular preparation, study of properties, or use, and suffice for the reproduction of the materials". Five panels were set up on composition, structure, defects, polycrystals and polymers. The first three covered methods used to improve characterization generally, while the last two were specific to the unique problems of two materials classes differing in structure. The study assessed the situation surrounding some of the greatest needs for characterization, i.e., (a) better techniques and instruments, or more and better use of existing techniques and instruments, (b) better characterization for improved preparation of materials, or for improved study of materials, or for improved use of materials, and (c) more accurate and detailed characterization of materials in general.

MAB-232-M GUIDELINES FOR REFRACTORY ALLOY TUBING SPECIFICATIONS (37 pp)

The report includes precautions, limitations, and guidelines which are intended to facilitate the preparation by a user of a specification for procuring tubing made from reactive or refractory metals.

MAB-236 STRUCTURAL DESIGN WITH FIBROUS COMPOSITES (127 pp)

The problem of designing structures with fibrous composite materials was examined and the advantages which can accrue from the use of such composites were briefly reviewed, and confirmed as outstanding in many cases. The substantial progress made in limited applications was recognized, but the report concentrated mainly on what must be done to benefit as fully as possible from these new materials and to minimize need for "cut-and-try" approaches to design objectives. Accordingly, major design difficulties were sought out and defined. Important among these was the difficulty in standardizing the tests needed to characterize many of the important composite material properties and in predicting them by theoretical analyses. The load transfer problem was cited as major, with only limited successes to date. Design with composites was recognized as being more intimately bound to fabrication than is design with conventional materials, and the need for design handbooks and specifications was identified as one part of an important communications, education, and acceptance problem.

MAB-238 TRENDS IN USAGE OF BERYLLIUM AND BERYLLIUM OXIDE (17 pp)

This report is one in a series of five (the others being molybdenum, platinum, silver, and tantalum), in which the influence on applications of changing technology is explored. It was found that forecasting consumption trends of beryllium and beryllium oxide is difficult; many possible applications, each having an important impact on consumption, have been advanced to the prototype stage, but further development of any one is problematical. However, applications of beryllium metal, such as guidance and nuclear components, were expected to

increase. In addition, relatively new uses, such as aerospace components and aircraft brakes, were expected to consume significant and growing quantities of metal.
The supply of beryllium was considered to be in reasonable balance with demand, but a close watch on the situation was recommended.

MAB-240 TRENDS IN USAGE OF PLATINUM (11 pp)
This report is one in a series of five (the others being beryllium, molybdenum, silver, and tantalum), in which the influence on applications of changing technology was explored. As the information on applications for platinum was fragmentary, a continuation of the subcommittee's activity (encompassing, in addition, palladium) was planned to develop more quantitative data. Findings were that (1) most platinum was used in catalytic operations (manufacture of nitric and sulphuric acid, hydrogenation of a variety of compounds, and reforming of gasoline), in the electrical industry, and as containers for molten glass, (2) if the supply of platinum became critical, much direct substitution of other materials for platinum was unlikely to occur--rather alternate processes to avoid its use might be resorted to, and (3) on the other hand, greatly increased demand for platinum for the reforming of gasoline could result if the lead content of gasoline were to be restricted.

MAB-241 TRENDS IN USAGE OF SILVER (15 pp)
This report is one in a series of five (the others being beryllium, molybdenum, platinum, and tantalum), in which the influence on applications of changing technology is explored. Little concern was expressed regarding present stockpile specifications, but it was noted that much Treasury silver is of low grade and unusable for many applications without refining. A possibly inadequate domestic refinery capacity may limit the rate at which this metal can be used. Findings were that the future supply of silver appeared to be inadequate, and that while no significant new applications were known and despite price increases, consumption continued to climb.

MAB-242 TRENDS IN USAGE OF TANTALUM (14 pp)
The demand for tantalum had been growing at a considerable rate, a rate which was apt to increase in the future. The extremely tight supply situation seemed to have eased. Findings were that nearly three-quarters of the tantalum produced went into electric equipment in the form of capacitors and that most such capacitors were used in military and space equipment, although there was a growing industrial market. Therefore, tantalum consumption was closely tied to defense spending. Use in electronic applications was expected to double in the next 5 to 10 years; no decrease in usage for any identified application was foreseen. Tantalum was found to be replaceable in chemical equipment by glass or by other refractory metals or platinum, but at an economic penalty due to the excellent heat transfer characteristics and fabricability of tantalum.

MAB-243 INFRARED TRANSMITTING MATERIALS (59 pp)
The committee on this subject was established to study the problem of developing bulk or castable glass that would transmit in the 8 to 14 micron range and still be capable of successfully resisting the high temperatures and mechanically induced stresses which are intrinsic to many current and projected infrared applications.
The principal conclusion was that prospects are limited for obtaining melt-formed glasses transmitting infrared radiation in the above-mentioned range, useful at elevated temperatures, and capable of large-size fabrication. Alternate routes were studied; these are documented in the report.

MAB-245 APPLICATION OF SCIENCE AND TECHNOLOGY TO METALWORKING (21 pp)
This study was made by a panel established under the Metalworking Processes and Equipment Program (see Report MAB-206-M(7)). The panel considered the application of science and technology to the development of new processes and equipment for enhancing the forming of high strength and refractory metals. Subjects covered in the report include high pressure

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forming, the General Electric Company's contact-bend-stretch mill, and the problems and needs for titanium mill products and shapes in the aerospace industry.

NMAB-246 AN APPROACH FOR SYSTEMATIC EVALUATION OF MATERIALS FOR STRUCTURAL APPLICATION (52 pp)

An approach is discussed which will enable the Services, the producers, and materials engineers to select those material evaluation tests which need to be performed for purposes of obtaining screening, selection, and design data. The necessary tests are indicated by a system which takes into account the vehicle, component, environment, and operational criteria. The system is based upon the preparation of a large number of applications case histories, the data from which must be recorded according to a rigid format. The compilation of case histories makes up what is called the Applications Analysis Data Bank. The system can be coded so that the case history data can be computer-analyzed to answer a number of pertinent questions for which answers are not easily obtainable at present. A complete materials evaluation system will consist of three data banks: (1) Applications Analysis, (2) Material Properties (these now exist), and (3) Material Evaluation Techniques. Examples are shown to demonstrate the workings of the proposed system and the many types of questions which can be answered. The necessary steps for the further development of the system are recommended.

MAB-247 TECHNOLOGICAL INFLUENCE ON USAGE OF PLATINUM AND PALLADIUM (19 pp)

Imports of platinum nearly doubled in the period between 1957 and 1967 and were 363,700 troy ounces in 1967. Palladium imports totaled 737,100 ounces in 1967. Since nearly 90% of the platinum and over 80% of the palladium were used in industrial applications, it appeared appropriate to assess the trends in future requirements and the possible substitutes for these metals. While some fields of application appeared to be declining, the general trend was for greater demand for both platinum and palladium. The limited substitution possibilities were discussed.

MAB-248 APPLICATIONS OF NICKEL (103 pp)

Production and consumption of nickel nearly doubled in the ten years beginning with 1957. Nickel is used in many important military and civilian applications which make use of stainless steel in a wide variety of ferrous and non-ferrous alloys and in plated components. Since production of the metal tended to lag behind needs for many years, it seemed desirable to examine the trend in applications and the possibility of substituting more plentiful materials in the event of an emergency. Stainless steels are the largest consumer of nickel, followed by superalloys, electroplating, and alloy steels. The function of nickel is not unique in practically any application. However, substitution will nearly inevitably result in a performance or an economic penalty. The report pointed out the substitution possibilities in a broad way. Any specific case, however, requires an engineering assessment which cannot be made in the abstract. The growth rates for the various applications of nickel were estimated.

MAB-249 USAGE OF TITANIUM AND ITS COMPOUNDS WITH COMMENTS ON SCRAP AND SPONGE (106 pp)

Present and anticipated uses for titanium are described in terms of both input weight and weight of titanium in the finished product. A nearly four-fold increase in the consumption of mill products (or about 100 million lb) is forecast by 1978. Airframe and engine applications account for about 90% of consumption, with desalination the major new non-aerospace potential application area. Utilization of scrap and quality of sponge are discussed as are uses of TiO_2.

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MAB-250 TRENDS IN USAGE OF HAFNIUM (11 pp)
Hafnium has important applications as a nuclear control rod material, as a base material for oxidation-resistant alloys (with columbium or tantalum), and as a minor constituent in tantalum-, columbium-, tungsten- and nickel-base alloys. The metal is obtained in amounts of 1-6% as a by-product of zirconium purification. Other applications, and the prospects for replacing hafnium with other metals, are mentioned in the report.

MAB-251 TRENDS IN USAGE OF RHENIUM (9 pp)
Rhenium is a rare, expensive, high-melting metal with some unique properties, including a ductilizing effect on several brittle refractory metals. It occurs as an impurity in molybdenite which is associated, in small amounts, with copper ores. Production and consumption have been less than a ton per year, with the potential production, while substantially larger, still definitely limited. Research is disclosing probable valuable applications, leading to the recommendation that efforts to conserve rhenium for probable future applications should receive support.

NMAB-252 NONDESTRUCTIVE EVALUATION (116 pp)
Nondestructive evaluation (NDE) must be incorporated into every phase of the design-production-service cycle, including the screening and qualification of materials for new design criteria, in order to design materials to their limits to satisfy the ever-increasing demands of sophisticated military systems. Even in the presence of adequate technology, the key to NDE implementation and maximum hardware reliability is the proper application of suitable specifications. To achieve the necessary reliability at reduced costs, a general management-control specification on the application of NDE to the design-production-service cycles should be prepared and included among the pertinent specifications in DoD contracts. Many of the technical problem areas in DoD hardware are well characterized and could be best handled by the proper use of NDE during the development and manufacture of materials and products. This requires selection of test parameters, design of tooling and definition of acceptance levels. Automatic data processing equipment must be employed to attain quantitative capabilities through rapid feedback of data for process control, comparison with prior data for early detection of trends and evaluation of operational changes. Review of special phenomena did not reveal any new energy form which could have impact on NDE techniques. Among areas recommended for further study were failure mechanisms, data processing, lasers, holography, acoustic propagation, and acoustic emission. A greater number of NDE professionals and technicians is needed and could be produced through increased university and other technical training. The establishment of national NDE research and application centers was recommended as was the expansion of the present DoD NDT Information Analysis Center.

NMAB-254 TRENDS IN USAGE OF GOLD (15 pp)
The United States production of gold is compared to the production in other free world countries. Developments which may contribute to an increase in domestic production in the near future are cited. Domestic consumption is reviewed by application. Totals for consumption in 1967 and 1968 are in good agreement with those compiled by the Office of Domestic Gold and Silver Operations of the U.S. Treasury Department. Growth patterns have been examined and estimates made on consumption as of 1973.
Expansion in domestic production will not keep pace with consumption demands. The growth in the use of gold is due to expansion of existing uses, particularly those of the electrical and electronic industry. No new technological developments appear on the horizon which would give rise to any precipitous change in the consumption of gold in the next five years.

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NMAB-255 TRENDS IN USAGE OF CADMIUM (15 pp)
This report is an analysis of the consumption of cadmium in the United States by individual end uses. It was determined that of the total consumption, electroplating accounts for roughly 50%, pigments about 20%, and constituents in stabilizers for polyvinyl chloride (a new use), about 20%. Most of that remaining is used in batteries and various metallurgical applications. Since cadmium is a by-product of zinc production, its supply is not very elastic. Forecasting its consumption pattern over a long period of time is hazardous because as a metal used in small amounts in numerous applications, its consumption is subject to changing technology.

NMAB-256 TRENDS IN USAGE OF CHROMIUM (88 pp)
Chromite ores of several grades (all imported) are used by the metallurgical industry as ferrochrome in the manufacture of stainless and alloy steels, by the chemical industry in pigments, plating and foundry facings; and in the refractory industry for linings in melting furnaces. These ores are available from Russia and Turkey (metallurgical), South Africa (chemical), and Phillipines (refractory). While chromium in decorative uses and in alloy steels can generally be substituted for, there is no adequate replacement for chromium in alloys designed for corrosion resistance, oxidation resistance, or for use at high temperature. For most chemical applications, materials bearing no chromium can be used in place of chromium-bearing materials at some cost or performance penalty--one notable exception is in drilling muds. In the refractory field, magnesite can be substituted in some applications, but chromium is necessary for others.

NMAB-257 USAGE PATTERNS FOR TELLURIUM (25 pp)
Since tellurium is recovered principally as a by-product from copper and lead refining, its supply depends greatly on copper and lead production. The United States has been the leading producer and consumer of tellurium in recent years. Production of tellurium by North American refiners is typically in the range of 200,000 to 250,000 pounds per year and consumption in the United States is also about the same level. The usage pattern is 79% metallurgical, 19% chemical and pharmaceutical, 1.5% thermoelectric, and the remainder electronic. In the metallurgical and chemical industries, tellurium is used as a secondary vulcanizing agent in the processing of both natural and GR-S synthetic rubber, a carbide stabilizing agent in the production of white cast iron, a machinability additive for carbon steel and copper, and an additive to lead to improve corrosion resistance. Tellurium consumption should grow moderately for the next several years. As the United States produces a large portion of its consumption, and procures most of the rest from Canada, no supply problems are anticipated.

NMAB-258 TRENDS IN USAGE OF MERCURY (37 pp)
Roughly one-quarter of the mercury consumed in the U.S. goes into electrical apparatus, another quarter to electrolytic cells, and 11 percent to paints. Uses in electrical apparatus, electrolytic cells, paint, and catalysts appear to be growing and now consume two-thirds of the total. No significant new uses were uncovered. Consumption is predicted to grow from the current rate of 73,855 flasks per year to about 83,544 flasks in 1974-1975. Recent price fluctuations have accelerated the search for substitutes. Only in a few areas do there appear to be technical and economic substitution possibilities; however, the trend is toward design to allow for the use of less mercury in each device.

NMAB-259 QUANTITATIVE TECHNIQUES FOR RESEARCH PROGRAM PLANNING IN STRUCTURAL MECHANICS (62 pp)
The Committee was formed to assist the structural mechanics branch of the Office of Naval Research to evaluate the title subject. It was concluded that (1) systematic procedures to assess the relative importance of various subdisciplines in structural mechanics have promise as methods for providing guidance in the allocation of research resources, (2) the discretionary judgment of the administration should enter into the allocation of all research funds,

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inasmuch as these procedures may not anticipate scientific breakthroughs, (3) twenty-five per cent (25%) of the research budget should be allocated to fundamental research exclusively on the judgment of the Branch staff members.

The matrix method is considered as the most promising planning technique. It was recommended that a trial program be established within the Structural Mechanics Branch of the Office of Naval Research (ONR) to explore the advantages resulting from the use of a quantitative method in the research planning process and to use the exercise as a learning process. The proposed study should extend over at least two budgetary cycles so that sufficient experience is accumulated for a realistic appraisal of the merits of the program. It was suggested that the trial program be monitored by a small advisory group.

NMAB-260 HOT CORROSION IN GAS TURBINES...MECHANISMS...ALLOY & COATING DEVELOPMENT...ENVIRONMENTAL EFFECTS...EVALUATION (70pp)

Hot corrosion (sulfidation) in gas turbine engines has become a major problem because of the increased use of alloys low in chromium and in operation in environments containing alkali metal salts, especially near sea water.

The mechanism of attack is understood to some extent, but more work is needed. It is clear that sodium and other alkali metal salts are involved. Sodium sulfate is ingested with the combustion air or formed from the sulfur in the fuel, and reacts with the metal oxide scale to form a complex sodium salt. After scale breakdown, sodium sulfate may attack the underlying metal, forming sulfides. The presence of NaCl in the gas and a liquid salt film seem to be required for accelerated attack. Coatings, alloy modification, and additives to the fuel all help alleviate the immediate problem. Alloy development, dispersion hardened and fiber strengthened alloys, and rare earth additions to superalloys may offer longer-range solutions. Target performance properties are needed to focus the future research and development work. Engine testing is still the only reliable evaluation method to check improvements in the hot corrosion resistance of materials. Test rigs are commonly used for a preliminary evaluation of hot corrosion resistance. Reproducibility in test results from test rigs in different laboratories is poor, and further effort is needed toward test rig standardization, correlation of the data between different tests, and interpolation of test results.

NMAB-261 FUNDAMENTALS OF MASSIVE GLASS AS A NAVAL STRUCTURAL MATERIAL (86 pp)

Future deep-sea operations by the Navy and others will necessitate the development of materials with properties superior to those currently available. Glass is one candidate for deep-submergence uses because of such favorable properties as potential high strength-to-weight ratio, transparency and corrosion resistance. However, before glass can be fully utilized for this purpose, additional information will be needed on its properties. This report contains recommendations for research on physical and mechanical properties and how to enhance them. Topics covered are strength, means of strengthening, structure, dynamic processes, glass ceramics, and fundamental phenomena. The recommendations are justified in a summary of available knowledge covering strength of glass, chemical strengthening, other methods of strengthening, transport properties, structure, vibrational properties, and glass ceramics. Many of the recommendations are essential to an understanding of the vitreous state and as such have application in fields other than structural glass.

NMAB-262 MASSIVE GLASS AS A NAVAL-STRUCTURAL MATERIAL (98 pp)

Massive glass has potential as a structural material for a variety of high efficiency, deep ocean applications. However, neither the existing data on massive glass nor current industrial production capability are adequate for the task, particularly if a date for producing a man-rated glass pressure hull is set for 1980.

The application of glass as a structural material for deep submergence has been reviewed and evaluated in this report. Specific areas of glass technology requiring research, development,

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testing and evaluation effort are described. A structural design scale-up program using models and full-size pressure hulls is suggested. Concurrent materials studies, design evaluation programs, and production development are recommended.

NMAB-263 SUMMARY REPORT--HIGH TEMPERATURE OXIDATION RESISTANT COATINGS (54 pp)

Coatings for superalloys, refractory metals, and graphite are described from the points of view of fundamental principles, specific substrate, and application. General and specific conclusions were reached, followed by recommendations for upgrading coating capabilities. This report constitutes a summary of a larger volume of the same title published by the National Academy of Sciences. (Publication No. ISBN-0-309-01769-6)

NMAB-264 TRENDS IN USAGE OF COLUMBIUM (75 pp)

Uses of columbium in various applications are reviewed and estimates are made of future requirements. Currently, major applications are as additions to ferrous alloys and superalloys. Superalloy consumption is expected to experience very rapid growth until 1972 and aerospace applications will probably utilize columbium-base alloys to a greater extent than heretofore. Some possible substitutes for columbium are also discussed. Basic to the demand for columbium is its availability. Both foreign and domestic resources are reviewed in light of past production and mineral reserves, as are the quantity and quality of columbium in the National Stockpile. Current resources exceed present demands, but the anticipated 20% annual increase in superalloy production is expected to put some strain on the availability of high purity Cb_2O_5, unless pyrochlore concentrate becomes a source.

NMAB-265 TRENDS IN THE USE OF TIN (52 pp)

About half of the primary tin used in the United States has gone into making tin plate. With the development of cans joined by welding or adhesives, a strong growth in the use of tin-free cans is expected. Under normal conditions, this development and other developments in substitute materials are expected to cause an annual decline of $1\frac{1}{2}\%$ during the 1970-1977 interval. While moderately higher requirements for tin in solders and for miscellaneous applications as a whole are prognosticated, reserves of tin appear to be adequate for twenty to forty years.

NMAB-266 TRENDS IN USAGE OF RARE EARTHS (67 pp)

The sources of rare earths are presented together with current and anticipated usage in various applications. There are several known and proposed domestic sources of light rare earths that give assurance of their availability under emergency conditions. The United States is not a significant producer of yttrium and the heavy rare earths; substantial price advances would be needed to increase the supply. Rare earths are used in the unseparated form (catalysts, nodulizer in irons, etc.). Individual applications are expected to change considerably with time but the overall usage trend is upward. Recently, the Government removed rare earths from the list of strategic and critical materials to be maintained in the national stockpile.

NMAB-267 TRENDS IN THE USE OF VANADIUM (46 pp)

The major source of vanadium in the future appears to be vanadium-bearing magnetite ores from which vanadium will be co-produced during steel manufacturing. The growth areas for vanadium in the steel industry are high-strength, low alloy steels (HSLA) and possibly as a deoxidant in continuous casting of steel slabs and billets. The demand for vanadium in these steels is predicted to exceed all other cumulative uses for vanadium--with HSLA steels making the biggest demand. In the face of a substantial price rise or of a shortage in vanadium, columbium could be substituted. As yet, the choice has not been made between stainless steels and vanadium alloys as a fuel element cladding in fast breeder nuclear reactors. Even if vanadium alloys are chosen for this application, the increase in demand will not be felt for approximately fifteen years.

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NMAB-268 TRENDS IN THE USAGE OF BISMUTH (30 pp)
Bismuth is obtained largely as a by-product from the ores of other metals, principally copper and lead. Accordingly, its availability is greatly dependent upon demand for the ores of metals with which it is found. Its principal uses are in low melting alloys, in metallurgical additives for aluminum, carbon steel, and malleable iron, in pearlescent pigments, in pharmaceuticals, and in a variety of other smaller specialized applications. In many of these uses, other materials may be substituted for bismuth. If bismuth prices and supply considerations continue as now anticipated, bismuth usage in the United States should expand at a somewhat slower rate than the gross national product during the next several years.

NMAB-269 TRENDS IN THE USAGE OF FLUORSPAR (34 pp)
Three major segments of the American industry (steel, aluminum, and fluorocarbons producers) require large and assured supplies of fluorspar. These industries will continue to be dependent on an adequate supply of fluorspar for beyond the next decade. Although demand from the aluminum industry may decrease slightly because of fluorine recovery from waste products and by-products fluorine from phosphate production, increasing requirements for the production of steel and fluorocarbons should cause the demand to rise continually. Secondary sources of fluorine are beginning to be exploited, the principal source being a byproduct from production of phosphates. The chemical and aluminum industries have indicated that some of the technological and economic problems involved in extracting fluorine from this by-product have been solved.

NMAB-270 ADVANCED TECHNOLOGY FOR NAVAL GUN TUBES (70 pp)
(for the Naval Ordnance Systems Command)
The object of this study was to recommend long-range improvements in the manufacture and concept of gun barrels, as well as to suggest solutions to current gun manufacturing problems. Improved steels are listed and coatings for the bore proposed which might result in better performance or lower cost. Alternate metalworking and casting methods are discussed. The manufacture and inspection of barrels are described and some advanced technology proposed. A limited number of advanced concepts for launching projectiles were examined. Of the conclusions reached the foremost two are the need for better understanding of the interrelationships among the factors responsible for the degradation of gun barrels during service, and the need for the consideration of a barrel as part of an ammunition-propellant-gun system and not as an isolated entity.

NMAB-271 FUNDAMENTALS OF DAMAGE IN LASER GLASS (80 pp)
In spite of the fact that substantial funds have been expended by both industry and the military, optically induced damage in glasses still limits the usefulness of laser-glass devices. It is believed that the existing material limitations are not insurmountable. It is therefore desirable to evaluate and review the efforts in various industrial and governmental laboratories to define the fundamental material limitations and to indicate steps in research and development necessary to reach those fundamental limits. The report of the Committee outlines the several problems that need to be overcome to permit production of a laser glass having a damage threshold of 100 joules per cm^2 while possessing the other qualities requisite for good high-durability laser glass. A program directed toward the solution of these problems is documented in the report.

NMAB-272 PROCEEDINGS OF THE BERYLLIUM CONFERENCE (VOL. I) (655 pp) *
The conference was staged at the suggestion of the Department of Defense (Office of Director of Defense, Research & Engineering) to put before designers of military hardware a wide variety of applications of beryllium, in order to insure that design situations in which the metal might be used profitably would not be overlooked or unjustifiably passed over. The sense of the presentations and of the resulting discussions is summarized in the first brief paper entitled "Overview." The hardware display and the case histories presented at the conference showed that beryllium

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has come of age as an engineering material. When the materials selection process ranks beryllium as a "best choice," the property data, design, fabrication, and inspection techniques are available to enable the production of reliable hardware.

* Can be obtained from National Academy of Sciences at a cost of $10. (See p. 4 of the text)

NMAB-274 TRENDS IN USAGE OF ANTIMONY (113 pp)

Over the 1969-1975 period, demand for primary antimony is expected to increase at an annual rate of 5.8 percent (or to a cumulative additional 25,000 tons of primary antimony) over 1969 production levels. Known world resources appear adequate to support present production for the above period. Sustained higher prices may stimulate increased production. Aside from its domestic resources, the U. S. antimony-consuming industry must look to its future sources of material from South Africa, Bolivia, and Australia. The fastest growing areas of primary antimony demand are as flame retardants in plastics and as catalysts. Total metallurgical usage of antimony is expected to grow at 1.5 percent per year, a decreasing rate of demand. However, batteries are projected to continue at a 3.0 percent annual growth rate, a relatively steady demand.
The Panel recommended that consumption statistics should be revised to emphasize the functional usage of antimony, and that the U. S. Geological Survey and the Bureau of Mines conduct a resource evaluation based on various antimony price levels.

NMAB-275 TRENDS IN THE USAGE OF DEPLETED URANIUM (172 pp.)

This report presents information on uranium and its compounds to assist in assessing the impact of changing technology on their future requirements. The data herein may stimulate greater interest in the usage of depleted uranium in nonnuclear applications, thus bringing its consumption in closer balance with its supply level. Topical areas include depleted uranium's supply situation, present nonenergy consumption, potential uses, metallurgy, chemistry, and effectiveness as a catalyst and alloying element. Current consumption for nuclear uses is small. The only major area of promise involving large quantities of depleted uranium is in breeder-power reactors where a development program is being supported by Government and industry. Current consumption of uranium for commercial nonnuclear applications is under 500 tons per year but this consumption is expected to grow as the properties of depleted uranium are exploited. Uranium can be safely fabricated and used with very few special precautions.

NMAB-276 TRENDS IN THE USE OF FERROALLOYS BY THE STEEL INDUSTRY OF THE UNITED STATES (116 pp.)

The demand for ferroalloy materials by the steel industry was reviewed and projected to 1980 with due consideration of anticipated technological change. National stockpile specifications for these materials were examined and certain specific changes were recommended. An improved definition of the superalloy class of materials was developed and a separate reporting of high-strength, low-alloy steel statistics by all data-gathering groups was recommended.

NMAB-277 A DELPHI EXPLORATION OF THE U.S. FERROALLOY AND STEEL INDUSTRIES (112 pp.)

This is a companion report to NMAB-276 (Trends in the Use of Ferroalloys by the Steel Industry of the United States), which represented a conventional approach to the problem. The Delphi technique involves a series of strategically organized questionnaires directed

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to a broader group of participants. The results of this exercise are interesting in terms of the significant number of uncertainties that were exhibited in relation to such subjects as scrap, pollution, geographical patterns, and foreign competition. A more positive note was struck in the judgment that new technology will lead to more efficient steelmaking and will aid in overcoming foreign competition. Comparisons are drawn between these findings and those of NMAB-276.

NMAB-278 PROCESSES FOR EXTRACTING ALUMINA FROM NONBAUXITE ORES (88 pp.)

The most promising domestic sources of supply for alumina (other than commercial bauxite) were reviewed, basic approaches to the processing of clay were examined, and the most workable processes were appraised. An acid process for the treatment of clay appeared to have the most potential for the economic production of alumina from materials other than commercial bauxite. Available experimental and pilot plant data on most of the alkaline processes for producing alumina from clay indicated that these processes normally were not competitive with acid processes. The technical feasibility of producing near reduction-grade alumina by the hydrochloric acid extraction from clay has been demonstrated on a small scale. Relatively large and extensive pilot-plant testing appears necessary to assess the economies of scaled-up production and to evaluate other economic factors. The economic recovery of alumina from other sources does not appear promising at present.

NMAB-279 TECHNOLOGICAL FORECASTING AND ITS APPLICATION TO ENGINEERING (41 pp.)

The major value of technological forecasting is in its contribution to planning and decision-making. Among the benefits that could be derived from engaging in a forecast of technical opportunities in materials are employing advanced materials technology, simplifying the selection of appropriate materials areas, identifying areas of most productive interdisciplinary activity, expanding the horizons of involved individuals, and reducing the possibility of surprise. The report lists the considerations involved in undertaking a technological forecast, and relates these considerations to the various methods of exploratory forecasting. Recommendations to DoD and other agencies include collection of time-related data for use in technical forecasting, initiation of a forecasting study on processing and fabrication, creation of courses in forecasting for engineering students, and inclusion of forecasting in long range planning.

NMAB-281 REPORT OF THE AD HOC COMMITTEE ON BERYLLIUM (93 pp.)

This review, made to examine the role of the Department of Defense in using beryllium and in advancing the technology, found numerous applications, such as guidance systems, re-entry vehicles, brakes, and thrust chambers, which would suffer significant performance penalties if beryllium were not available. Several design trade-offs show beryllium to be competitive with, or superior to filamentary composites, on a stiffness-to-weight basis, in advanced applications for lightweight structures. Increased usage of beryllium, however, will be unlikely without certain necessary development work which is described. Civilian applications are limited because beryllium remains an expensive material. Accordingly, fulfillment of beryllium's potential advantages for military systems requires government support to ensure that beryllium in the required forms will be available, particularly for applications now being designed. Evaluation of some of the newer fabrication operations in terms of cost and applicability are recommended as are the

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construction and evaluation of prototype hardware, to capitalize on available beryllium technology, and to establish the experience, data base, and confidence necessary to keep beryllium as a viable candidate for future military systems.

NMAB-283 ACCELERATED UTILIZATION OF NEW MATERIALS (96 pp.)
Because of concern regarding the slow rate of introducing new materials into National programs, the Committee sought to identify the factors that promote or inhibit their use. The advantages to be derived from new materials are documented. Case histories of past material introductions are discussed. Using these histories as a foundation, the factors that constrain or which promote progress in introducing new materials into hardware are identified. The Committee recommends (1) establishment of a governmental group to identify new materials with wide applicability that can benefit by coordinated support and to organize a cooperative program for development of such materials, (2) provision of a contractual clause to allow for incentive payments to compensate for the cost involved in achieving levels of performance beyond the minimum specified, (3) utilization of present hardware systems as test beds for materials development in components and (4) consideration of benefits over the full lifetime of the system in materials cost analysis.

NMAB-284 FUNDAMENTALS OF AMORPHOUS SEMICONDUCTORS (187 pp.)
The study of glasses has been important historically because of the great usefulness of these disordered materials. Members of a comparatively new class of these materials, the amorphous semiconductors, have evoked interest in the last few years because they exhibit certain unique properties (semiconductivity, photoconductivity, low sensitivity to high-energy radiation, and ease of undergoing phase changes) which should be of considerable technological significance. The committee which considered this topic recommended increased effort in activities such as gathering of data on physically realized glass structures, development of better methods of material preparation and characterization, investigations leading to better understanding of structure control and radiation hardness, and research aimed at the technological exploitation of unique properties.

National Academy
of Sciences Publication
No. 1576 CERAMIC PROCESSING (298 pp)*
Earlier studies by the Materials Advisory Board, in 1961 and 1963, emphasized that a detailed examination of ceramic processing was a necessary step toward obtaining reliable high-integrity ceramic materials with superior properties. Such an investigation was requested of MAB by the Department of Defense, and this book is the result of the study. Four panels were formed under the main committee, on Solid Processing, Fluid Processing, Finishing and Evaluation. Technical recommendations of the report are that (1) the starting material should be fully characterized as should each step in processing, (2) new tools and techniques should be provided to characterize material in process and the final product, (3) particular attention should be paid to the character of the ceramic surface,(4) standardized lots of starting materials and standard test methods be made available, (5) the scientific approach should be used to overcome limitations in size without sacrificing reliability, and (6) improved understanding of character-property relationships must be developed. Non-technical recommendations are that the essentials propounded in the report be brought forcefully to the attention of all concerned, and that interdisciplinary programs be developed including consortia among universities, research laboratories and industry, to tackle the problems in a pragmatic manner.

* Can be obtained at a cost of $15.00 from National Academy of Sciences. (See p. 4 of text)

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National Academy
of Sciences Publication
ISBN-0-309-01769-6 HIGH TEMPERATURE OXIDATION RESISTANT COATINGS *
(224 pp.)

In recent years, superalloys, refractory metals, and graphite have been used increasingly for a variety of aerospace, propulsion, and industrial applications. This report presents a comprehen sive review of the science and technology of coatings used to protect these structural materials. It considers the basic concepts and principles of coating systems, analyzes mechanisms of coating degradation, and presents an objective analysis of the capabilities and limitations of various coating systems in terms of specific applications. The book also describes the availability of laboratory and manufacturing processes and facilities for the application of high-temperature protective coatings to refractory metals, superalloys and graphite. In addition, it reviews inspection and testing procedures and recommends research and development programs that may lead to advances in coating technology. These recommendations relate to such areas as new deposition processes, recoating processes, automated manufacturing processes, new approaches tc coating development, and (for current systems) greater understanding of mechanisms governing coating behavior and fuller characterization and evaluation at the hardware stage.

* Can be obtained at a cost of $12.50 from National Academy of Sciences.